FINAL WORK PLAN
PILOT-SCALE EVALUATION OF HYDROGEN RELEASE COMPOUND FOR ENHANCED IN-SITU BIOREMEDIATION AT AOC 50

DEVENS RESERVE FORCES TRAINING AREA
DEVENS, MASSACHUSETTS

CONTRACT DACA31-94-D-0061
DELIVERY ORDER NO. 0007

U.S. ARMY CORPS OF ENGINEERS
NEW ENGLAND DISTRICT
CONCORD, MASSACHUSETTS

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1.0 INTRODUCTION

Remedial investigation activities at Area of Contamination (AOC) 50 at Devens Reserve Forces Training Area (RFTA) have identified a plume of tetrachloroethene (PCE) contaminated groundwater migrating from a source area near Building 3840 toward the Nashua River approximately 3,000 feet away (Figure 1). As part of the Remedial Investigation/Feasibility Study Process, several potential approaches will be evaluated for cleanup of source-area and groundwater contamination. In support of the feasibility study, the Army has directed HLA to perform a pilot-scale test of one of the potential remedies: enhanced in-situ bioremediation.

The chlorinated solvent PCE degrades only slowly by biological processes under aerobic conditions. Degradation is relatively rapid, however, under anaerobic conditions, and, through a process called reductive dechlorination, PCE is sequentially degraded/transformed to the daughter products trichloroethene (TCE), dichloroethene (DCE), vinyl chloride (VC), and ultimately to innocuous nonchlorinated compounds. The presence of low concentrations of DCE and VC near the AOC 50 source suggests that some anaerobic degradation has taken place, but the high concentrations of PCE, presence of dissolved oxygen, and low concentrations of total organic carbon suggest that conditions are not favorable for it to continue. The degradation sequence is shown below.

PCE > TCE > DCE > VC > nonchlorinated compounds

In this process, PCE/TCE/DCE/VC serve as terminal electron acceptors during the microbiological metabolism of organic carbon. The microorganisms preferentially use several other electron acceptors before PCE/TCE/DCE/VC; however, so there must be a relatively large carbon (electron donor) source available to the microorganisms if the process is to occur. These other electron acceptors include dissolved oxygen, nitrate/nitrite, and sulfate. If there is sufficient organic carbon in the groundwater naturally, the process may proceed on its own. This degradation, along with dilution and dispersion, can result in the natural attenuation of the PCE. If sufficient carbon is not available naturally, adding it by injection or other means may initiate and sustain the degradation process. Potential carbon sources include lactic acid, propionic acid, acetate, ethanol, and even molasses. Adding carbon with the intent of stimulating or maintaining the degradation process is the basis of enhanced in-situ bioremediation.

2.0 OBJECTIVES OF PILOT-SCALE TESTING

The objectives of pilot-scale testing of enhanced in-situ bioremediation at AOC 50 include the following:

- assessing whether conditions suitable for anaerobic degradation of PCE can be induced by addition of a carbon source at AOC 50
- characterizing the type of microbial processes being supported (e.g., iron reduction, methanogenesis)
- collecting data to estimate the rate of sequential dehalogenation of PCE, TCE. DCE, and VC
- collecting data to estimate lateral dispersivity; this will be useful to full scale remedial design

3.0 GENERAL APPROACH

HLA proposes to evaluate enhanced in-situ bioremediation using Hydrogen Release Compound (HRC™), a commercially available, environmentally-safe, food-quality product marketed for this application by Regenesis, headquartered in San Clemente, California. HRC™ is a viscous polylactate ester specially formulated for slow release of lactic acid upon hydration. In use, HRC™ is injected directly into the subsurface through one, or a series of, injection points using direct push (or equivalent) techniques. Native microorganisms metabolize the lactic acid which results in the release of hydrogen (H_2). The hydrogen is in turn used by another group of microorganisms in the reductive dechlorination of chlorinated compounds.

Studies have shown that PCE and TCE are degraded quickly to DCE under anaerobic conditions. The degradation of DCE to VC and VC to ethene is slower, but does occur under strongly reducing conditions without the use of oxygen enhancements ("Technical and Regulatory Requirements for Enhanced In Situ Bioremediation of Chlorinated Solvents" Interstate Technology and Regulatory Cooperation Workgroup, 1998). Monitoring during the pilot test will allow assessment of DCE and VC degradation within overburden groundwater. Pilot-scale activities consist primarily of injecting HRC™, collecting groundwater samples to monitor subsurface conditions, and interpreting data.

If HRC™ is effective at creating conditions suitable for degradation of PCE, then the feasibility study will evaluate the advantages and disadvantages of HRC™ and other electron donors for full scale implementation.

Full scale implementation of enhanced in-situ bioremediation using HRC™ would require consideration of hydraulic dispersivity, conductivity, and groundwater velocity to asses optimal HRC™ injection rate and pattern. A software program developed by Regenesis considers these factors to calculate HRC™ loading rates for either barrier or grid injection patterns. Data from the pilot test will be used to confirm the applicability of the enhanced bioremediation program and confirm dispersivity assumptions.

4.0 PILOT-SCALE TEST DESIGN

There are two basic approaches for design of enhanced in-situ bioremediation. One is a grid-based approach in which the enhancement is injected in a grid pattern across the length and width of the contaminant plume. This approach achieves cleanup in a relatively short period of time, but requires a large number of injection points and may not be cost-effective for large areas. The other approach is injection along a row of delivery points oriented perpendicular to groundwater flow to create a treatment barrier. This approach may require multiple injections and take longer than the grid-based approach, but be more cost effective for large areas. Regenesis' experience is that HRC™ can be formulated and injected such that it will persist for up to a year before complete dissolution/dispersion, at which time reinjection is necessary. The length of time needed to cleanup a groundwater plume is inversely proportional to the number of injection/treatment barriers (e.g., installation of two treatment barriers, one at the toe of a plume and one at the midpoint would cut cleanup time in half).

Based on these considerations, HLA proposes testing the barrier design approach for treating overburden groundwater. The portion of the plume proposed for testing is not closely associated with underlying bedrock, and assessment of HRC™ effectiveness for bedrock remediation is not planned. In addition, it is believed that the PCE migration pathway in bedrock at AOC 50 is short and that the plume re-emerges into the overburden aquifer where it would be more readily treated.

Information from the test (e.g., assessment of process feasibility, characterization of microbial processes, degradation rates, and dispersivity) would, however, also have applicability to a full-scale grid-based design. The Feasibility Study will examine optimal strategies for HRC™ application from time and cost standpoints.

The primary components of the pilot-scale testing program include:

- Identifying a suitable pilot-test location,
- Placement of HRC™ injection points and monitoring wells,
- HRC™ injection, and
- Groundwater monitoring.

4.1 IDENTIFICATION OF A SUITABLE PILOT-TEST LOCATION

The objective in selecting the location for the pilot test was to identify an area that will enable the Army to best evaluate the effects of the proposed bioremediation enhancing compound. The following criteria were considered during selection of the proposed pilot-test area:

- concentrations of PCE in groundwater should be approximately two orders of magnitude (or more) greater than the analytical detection limit (i.e., greater than approximately 100 micrograms per liter[µg/L]) (ESTCP, 1998),

- concentrations of PCE in groundwater should be higher than those of the degradation daughter products (i.e., TCE, cis-1,2-DCE, and vinyl chloride),

- hydraulic conductivities (K) should be greater than 10^{-5} centimeters per second (cm/sec) and preferably greater than 10^{-4} cm/sec to allow effective distribution of electron donor (ESTCP, 1998),

- groundwater velocities (V) should be conducive to reasonable physical and temporal dimensions for the pilot test (V = 0.2 to 1.0 feet per day [ft/day]) (ESTCP, 1998),

- concentrations of BTEX in groundwater should not be elevated (i.e., not greater than approximately 1 milligram per liter[mg/L]),

- if possible, existing monitoring wells should be incorporated into the pilot-test design,

- the pilot-test area should be readily accessible and pilot operations should not interfere with site activities.

Following review of these criteria, HLA selected a location at the southwest edge of MAAF and near groundwater screening point XSA-97-46X and monitoring well G6M-98-32X (see Figure 1). This monitoring well is located along the inferred centerline of the PCE plume. PCE concentrations of 2,100 µg/L were measured at screening point XSA-97-46X at 130 to 135 feet below ground surface (bgs.) during field screening activities. PCE concentrations of 760 and 660 µg/L were measured in samples from monitoring well G6M-98-32X (also screened at 130 to 135 ft. bgs.) in January 1999 and July 1999, respectively. In addition, a PCE concentration of 1,600 µg/L was measured at screening point XSA-97-45X, approximately 90 ft to the west, at 128 to 133 ft bgs. The following table compares the elevation of the screened intervals for these three sample locations.

Sampling Location	Ground Surface ft MSL	Screen Depth ft	Screen Elevation ft MSL
XSA-97-45X	265.1	128 - 133	132.1 - 137.1
XSA-97-46X	264.5	130 - 135	129.5 - 134.5
G6M-98-32X	265	130 - 135	130 - 135

Hydraulic conductivities are not available for monitoring well G6M-98-32X, but are in the range of 10^{-5} to 10^{-3} cm/sec at other MAAF locations (e.g., G6M-92-06X, G6M-97-

06B, G6M-97-08B, G6M-97-28X, G6M-97-29X). Estimated groundwater velocities of approximately 0.3 ft./day in the vicinity of monitoring well G6M-98-32X were an important factor in selecting that location for the pilot test. Groundwater velocities vary from approximately 0.03 ft/day near the source area to 0.3 ft./day at G6M-98-32X. At a velocity of 0.03 ft/day, placement of downgradient monitoring wells at the desired approximate equivalent of 30 and 60 days travel time downgradient of the HRC™ injection point results in only 1 to 2 ft. of separation, too close to maintain the hydraulic independence of injection and monitoring wells. At a groundwater velocity of 0.3 ft./day, 30 and 60 day travel times correspond to approximately 10- and 20-ft. distances, which are more reasonable dimensions. These distances are based on groundwater velocities, without adjustment for retardation.

In addition, BTEX and the daughter products TCE and DCE were not detected in the January and July samples from G6M-98-32X, and the area is removed from most airfield activities, yet is readily accessible. Because monitoring well G6M-98-32X was constructed with only a 5-ft screen, it is not planned to be among the primary monitoring wells for the pilot test..

Selection of this area for the pilot test does not mean that this would be the location for full scale application if enhanced in-situ bioremediation was chosen as a remedial technology. Potential locations, including this one, would be evaluated in the feasibility study.

4.2 HRC™ INJECTION

To facilitate interpretation of data, HRC™ injection points will be located along a straight line perpendicular to the main axis of the plume and the interpreted direction of groundwater flow. HLA proposes injection of HRC™ using a GeoProbe or equivalent. Injection will be accomplished over a 2- to 3-day period by pushing five drive points spaced six feet apart to the maximum injection depth and then injecting HRC™ at a rate of approximately 6.3 lbs. per foot over the 142 to 122 ft. bgs. interval (elevation = 123 to 143 ft. MSL) as the point is withdrawn. This depth corresponds to the area with the interpreted highest concentration of PCE at this location as shown in Figures 2 and 3.

Based on assessment of plume configuration interpreted from field screening data and groundwater modeling results, vertical dispersion is expected to be low in the vicinity of the pilot test and play a minor role compared to lateral dispersion. It is unlikely that vertical dispersion could be observed across the dimensions of the pilot test. However, to minimize possible effects from vertical dispersion and/or vertical gradients, the pilot test proposes inject HRC™ over a 20-ft interval and to monitor a narrower vertical interval. The Army expects that the results of the pilot test will help bound or more tightly determine lateral dispersivity values. Injection and monitoring across a wider vertical interval are not necessary to meet pilot test objectives. The spacing between points is based on a software program developed by Regenesis and on measured concentrations of DO, NO_3, SO_4, and PCE, as well as on independent assessment by the Army. Based on

preliminary estimates of groundwater dispersion, the "cones" of dispersing HRC™ from neighboring injection points should overlap after a few feet of downgradient travel.

To obtain additional data on dispersivity, it is proposed to spike the HRC™ with a conservative tracer (sodium bromide[NaBr]).

4.3 Location of Groundwater Monitoring Wells

Five groundwater monitoring wells are proposed; one upgradient well and four downgradient wells. The upgradient well will be located the approximate equivalent of 30-days travel time upgradient of the injection points, and two of the downgradient wells will be located the approximate equivalent of 30- and 60-days travel time downgradient, respectively. In addition, third and forth monitoring wells will be located approximately 60-days travel time downgradient, but slightly crossgradient to provide dispersivity data. Based on available data and groundwater modeling performed during preparation of the RI report, the estimated groundwater velocity in the vicinity of monitoring well G6M-98-32X is approximately 0.3 ft./day. The new monitoring wells will be screened across the 127 to 137 ft. bgs. interval (elevation = 128 to 138 ft. MSL). Monitoring well G6M-98-32X is screened over the 130 to 135 ft. bgs. interval (elevation = 130 to 135 ft. MSL), and will not be one of the primary monitoring wells for the pilot study.

To confirm the appropriateness of the planned depth and location of monitoring wells and injection points, groundwater samples will be collected with a hydropunch, screened auger, or equivalent from the proposed upgradient well over the approximate 125 to 140 ft bgs interval for field analysis/screening with a PhotoVac 10S Plus, Portable Gas Chromatograph. The planned location and depth of monitoring wells and injection points may be changed based on the monitoring data.

4.4 Groundwater Monitoring

Groundwater samples will be collected from the five monitoring wells on a regular basis to monitor the progress of the pilot test. Table 1 shows the analytical parameters, and Table 2 shows the planned sample collection frequency. It is anticipated that the pilot program will require six months for completion; however, an additional 3 months could be required depending upon the time needed for biodegradation to begin (an acclimation period of 2-3 months for the microorganisms is typical).

Samples will be collected using low-flow low-stress sampling techniques. It is anticipated that dedicated bladder pumps will be installed in each monitoring well to facilitate the sample collection process. The field parameters of dissolved oxygen, ORP, specific conductance, pH, and temperature will be measured using a flow-through cell connected to the discharge of the sampling pump.

New groundwater monitoring wells will be constructed of 2-inch ID PVC pipe with 10-ft. lengths of 0.01-inch slotted PVC screen. Sand pack will extend 5 ft above the top of the screen, a 5-ft. bentonite seal will be placed above the sand, and the well annulus will be grouted to the ground surface. To minimize potential disturbance of the aquifer and introduction of drilling water, monitoring well installation will be performed with plugged augers or other low-water-use methodology. Because a soil boring log is available for monitoring well G6M-97-29X (see attachment), collection of split-spoon samples for logging the new monitoring wells is not planned.

5.0 DATA REVIEW AND REPORTING

Data collected from the pilot test will be reviewed to evaluate the following:

- whether reducing conditions are established within the subsurface;
- the rate of biodegradation for individual cVOCs;
- the type of microbial processes supported within in the pilot-scale test area (e.g., iron reduction, methanogenesis); and
- the optimal spacing for injection points in a full-scale application.

Analytical results will be provided to USEPA, MADEP, and the Army on an interim basis as they are received. Complete data and results will be summarized and provided in a concise pilot-test report at the conclusion of the pilot test.

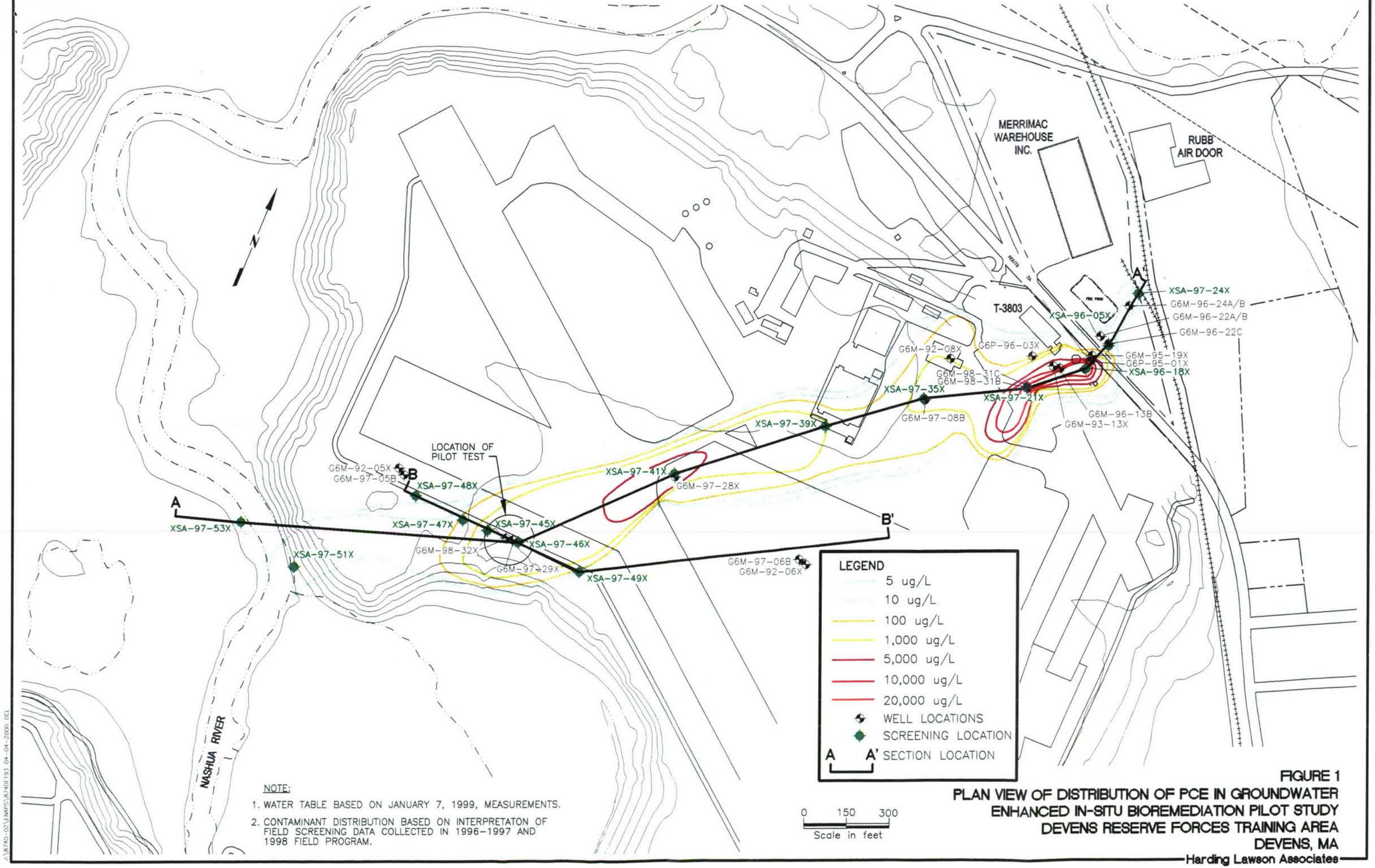

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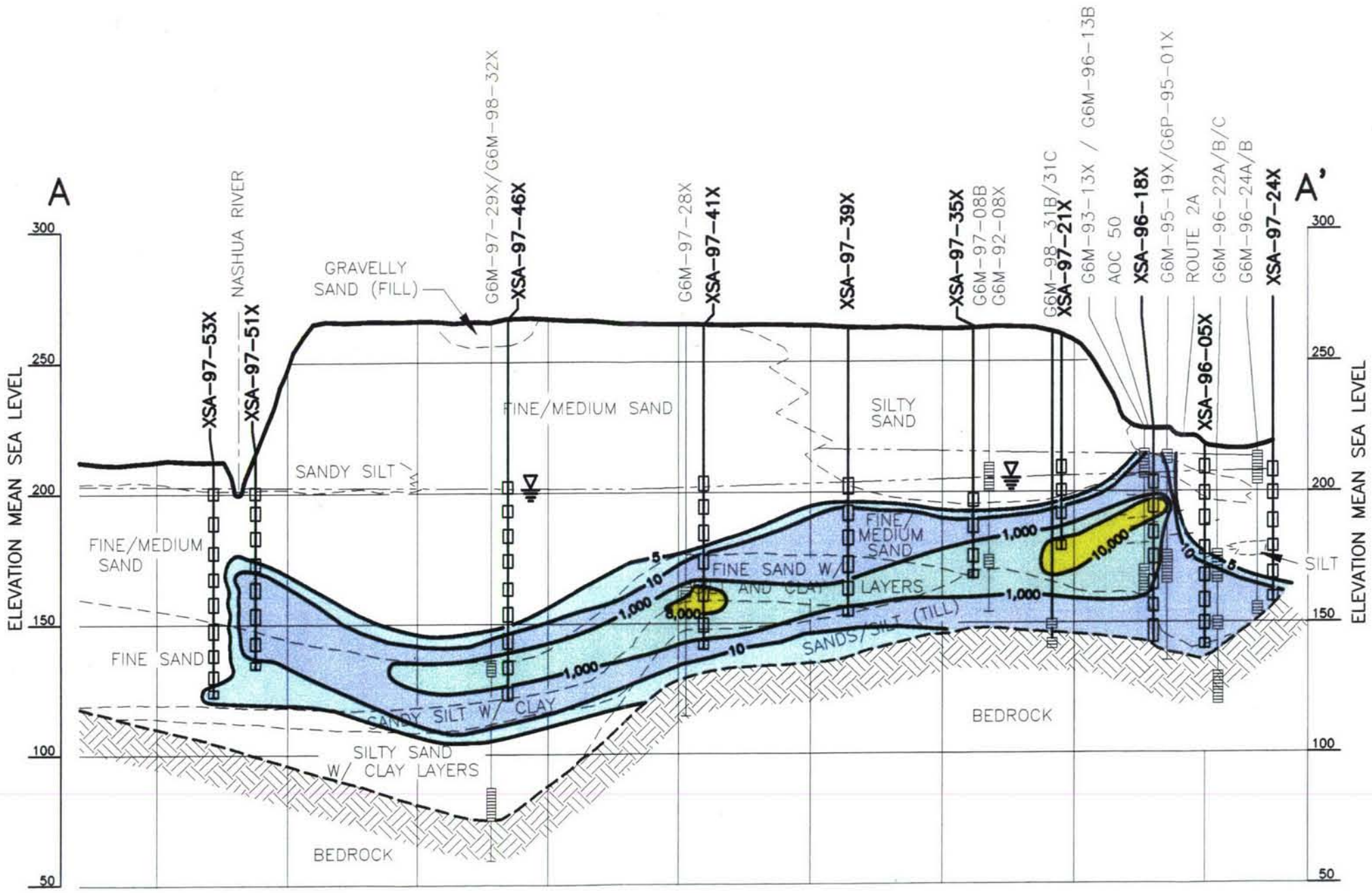
FIGURE 1
PLAN VIEW OF DISTRIBUTION OF PCE IN GROUNDWATER
ENHANCED IN-SITU BIOREMEDIATION PILOT STUDY
DEVENS RESERVE FORCES TRAINING AREA
DEVENS, MA
Harding Lawson Associates



XSA-97-46X
G6M-97-29X

LEGEND

EXPLORATION IDENTIFIER

GROUND SURFACE

WATER TABLE SURFACE

CLAY/SILT LENS

INTERPRETED STRATIGRAPHIC OR LITHOLOGIC BOUNDARY

GROUNDWATER FIELD ANALYTICAL SAMPLE

MONITORING WELL SCREENED INTERVAL

BOTTOM OF EXPLORATION

10 — PCE CONCENTRATIONS

PCE CONCENTRATIONS

- 5 TO 100 ug/L
- 100 TO 1,000 ug/L
- 1,000 TO 8,000 ug/L
- > 8,000 ug/L

NOTE:

1. WATER TABLE BASED ON JANUARY 7, 1999, MEASUREMENTS.
2. CONTAMINANT DISTRIBUTION BASED ON INTERPRETATON OF FIELD SCREENING DATA COLLECTED IN 1996–1997 AND 1998 FIELD PROGRAM.

0 200 400 800 FEET

SCALE: 1"=400' HORIZONTAL
SCALE: 1"=50' VERTICAL

FIGURE 2
DISTRIBUTION OF PCE IN GROUNDWATER ALONG CROSS SECTION A-A'
ENHANCED IN-SITU BIOREMEDIATION PILOT STUDY
DEVENS RESERVE FORCES TRAINING AREA
DEVENS, MA

Harding Lawson Associates

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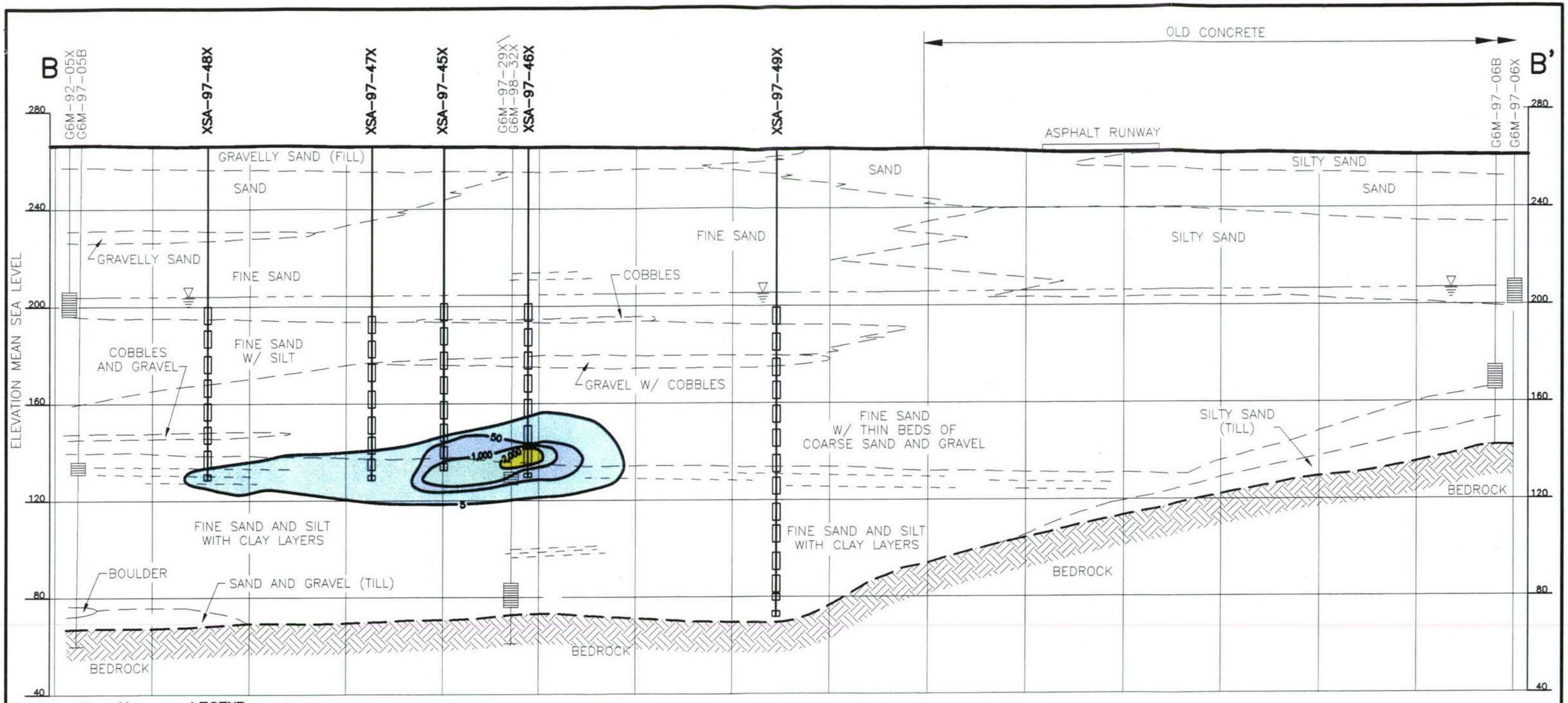

LEGEND

XSA-97-48X — EXPLORATION IDENTIFIER

G6M-97-29X

GROUND SURFACE

WATER TABLE SURFACE

CLAY/SILT LENS

INTERPRETED STRATIGRAPHIC OR LITHOLOGIC BOUNDARY

GROUNDWATER FIELD ANALYTICAL SAMPLE

MONITORING WELL SCREENED INTERVAL

BOTTOM OF EXPLORATION

10 — PCE CONCENTRATIONS

PCE CONCENTRATIONS

- 5 TO 50 ug/L
- 50 TO 1,000 ug/L
- 1,000 TC 2,000 ug/L
- > 2,000 ug/L

0 50 100 200 FEET

SCALE: 1"=100' HORIZONTAL
SCALE: 1"=40' VERTICAL

NOTE:

1. WATER TABLE BASED ON JANUARY 7, 1999, MEASUREMENTS.
2. CONTAMINANT DISTRIBUTION BASED ON INTERPRETATON OF FIELD SCREENING DATA COLLECTED IN 1996–1997 AND 1998 FIELD PROGRAM.

FIGURE 3
DISTRIBUTION OF PCE IN GROUNDWATER ALONG CROSS SECTION B-B'
ENHANCED IN-SITU BIOREMEDIATION PILOT STUDY
DEVENS RESERVE FORCES TRAINING AREA
DEVENS, MA

Harding Lawson Associates

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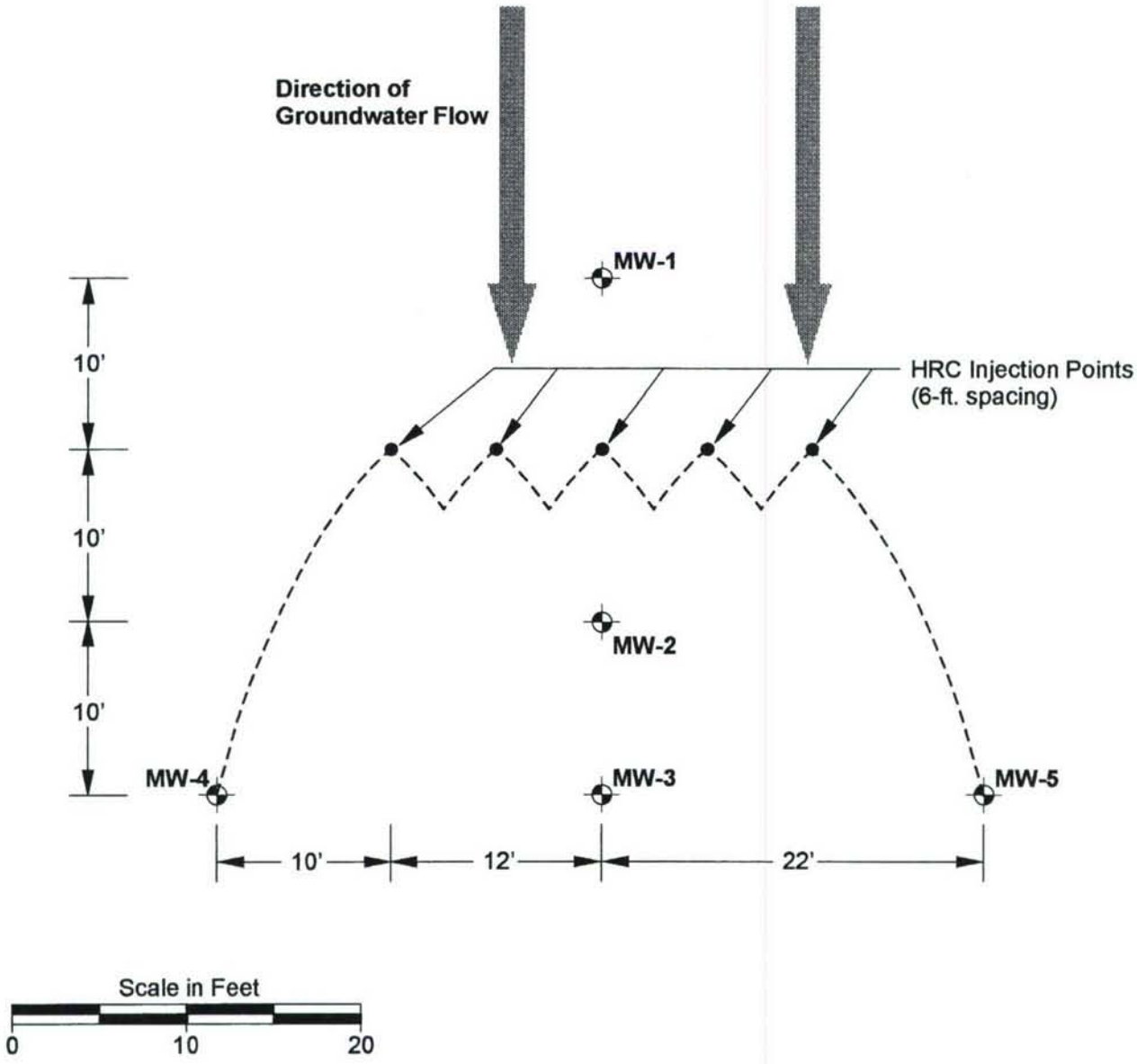

FIGURE 4
HRC PILOT TEST LAYOUT
ENHANCED IN-SITU BIOREMEDIATION PILOT STUDY
DEVENS RESERVE FORCES TRAINING AREA
DEVENS, MA

Harding Lawson Associates

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Table 1. Analytical Parameters

Parameter	Purpose	Method	Lab
Dissolved oxygen	Monitors concentration of available electron acceptor and whether anaerobic pathway may be present.	Meter with flow-through cell (USEPA Method 360.1)	Field measurement
ORP	Used to monitor whether an anaerobic pathway may be present.	Meter with flow-through cell	Field measurement
pH	Biological processes are sensitive to pH.	Meter with flow-through cell (USEPA 150.1)	Field measurement
Specific conductivity	May indicate changes in groundwater chemistry.	Meter with flow-through cell	Field measurement
Temperature	Biological processes are sensitive to temperature.	Meter with flow-through cell	Field measurement
Halogenated VOCs (cVOCs)	Monitors changes in PCE and breakdown product concentrations.	USEPA 8021B or equivalent	Off-site lab
Volatile fatty acids (lactic, propionic, pyruvic, and acetic)	Monitors changes in HRC™ and breakdown product concentrations.	HPLC	Off-site lab
Dissolved gases (ethene, ethane, methane)	Monitors changes in PCE breakdown product concentrations.	USEPA 8015B	Off-site lab
Total organic carbon	Indicator for concentration of electron donor.	USEPA 415.1	Off-site lab
Nitrate/nitrite nitrogen	Monitors concentration of available electron acceptor.	USEPA 353.1 (or equivalent)	Off-site lab
Sulfate	Monitors concentration of available electron acceptor.	USEPA 300 (or equivalent)	Off-site lab
Chloride	Product of reductive dechlorination of chlorinated compounds.	USEPA 300 (or equivalent)	Off-site lab
Bromide	Used to assess groundwater dispersion.	USEPA 300 (or equivalent)	Off-site lab
Sulfide	Product of sulfate reduction. Indicative of anaerobic conditions.	USEPA 376.1 (or equivalent)	Field measurement using test kit or off-site lab
Filtered/ferrous iron	Indicative of iron (III) reduction and anaerobic conditions.	Hach Kit (field), Standard Method 3500 (lab)	Field measurement using test kit or off-site lab

Table 2
Sample Collection Schedule

Monitoring Well and Analysis	Elapsed Time								
	0	2 Weeks	4 Weeks	6 Weeks	2 Months	3 Months	4 Months	5 Months	6 Months
MW-1									
Field parameters	✓	✓	✓	✓	✓	✓	✓	✓	✓
cVOCs/acids/gases	✓	cVOCs	cVOCs		cVOCs	cVOCs	cVOCs		
TOC	✓	✓	✓		✓	✓	✓		
Inorganics	✓	✓	✓		✓	✓	✓		
MW-2									
Field parameters	✓	✓	✓	✓	✓	✓	✓	✓	✓
cVOCs/acids/gases	✓	✓	✓	✓	✓	✓	✓	✓	as
TOC	✓	✓	✓	✓	✓	✓	✓	✓	needed
Inorganics	✓	✓	✓	✓	✓	✓	✓	✓	
MW-3									
Field parameters	✓	✓	✓	✓	✓	✓	✓	✓	✓
cVOCs/acids/gases	✓		✓	✓	✓	✓	✓	✓	✓
TOC	✓		✓	✓	✓	✓	✓	✓	✓
Inorganics	✓		✓	✓	✓	✓	✓	✓	✓
MW-4 & MW-5									
Field parameters	✓	✓	✓	✓	✓	✓	✓	✓	✓
cVOCs/acids/gases	✓		✓	✓	✓	✓	✓	✓	✓
TOC	✓		✓	✓	✓	✓	✓	✓	✓
Inorganics	✓		✓	✓	✓	✓	✓	✓	✓

Notes:
✓ = indicates analysis for listed parameters.
Field parameters = dissolved oxygen, ORP, pH, specific conductivity, and temperature.
cVOCs = chlorinated volatile organic compounds.
When listed under a time interval, indicates analysis for cVOCs, but not acids/gases.
Acids = lactic, propionic .pyruvic, and acetic acids.
TOC = total organic carbon
Inorganics = nitrate/nitrite, sulfate, chloride, bromide, sulfide, and iron.

ATTACHMENT

Soil Boring Log For G6M-97-29X

SOIL BORING LOG FORT DEVENS, MA PROJECT NO.: 8740.02

CLIENT: USAEC
CONTRACTOR: EEI
LOGGED BY: LT
METHOD: DRIVE & WASH
CASING SIZE: 5" TO 29', 4" TO 149', 3" TO 194'
DATE STARTED: 4/14/97
DATE COMPLETED: 4/29/97
PROTECTION: D

BORING NO.: G6M-97-29X
STUDY AREA: AOC-50
SOIL DRILLED: 190.5'
TOTAL DEPTH: 204.0'
WATER LEVEL: 56'
PID METER: 580B OVM

SAMPLE NO.	DEPTH	REC.	PID (ppm)	BLOWS PER 6"	SOIL/ROCK DESCRIPTION AND PHYSICAL CONDITIONS	USCS
S-1	4-6'	1.3'	bkg.	3,1,1,2	Brown fine sand, trace medium to coarse sand, gravel, little silt, moist, poorly graded, very loose. Introduced water prior to S-2.	SP-SM
S-2	9-11'	0.7'	bkg.	6,3,2,2	Similar to S-1.	SP-SM
S-3	14-16'	0.6'	bkg.	12,15,11,13	Brown fine sand, trace silt, saturated, medium dense, poorly graded.	SP
S-4	19-21'	0.7'	bkg.	19,14,13,13	Similar to S-3, with trace medium to coarse gravel.	SP
S-5	24-26'	0.4'	bkg.	22,13,11,11	Similar to S-4.	SP
S-6	29-31'	0.9'	bkg.	16,12,15,19	Similar to S-4.	SP
S-7	34-36'	0.8'	bkg.	12,16,15,21	Similar to S-4, dense.	SP
S-8	39-41'	0.9'	bkg.	14,17,18,17	Brown fine sand, some silt, wet-moist, poorly graded, dense.	SM
S-9	44-46'	1.0'	bkg.	13,19,24,28	Similar to S-8 except little silt (with horiz. rust-brown staining), saturated.	SM-SP
S-10	49-51'	1.1'	bkg.	21,19,24,27	Similar to S-8 with silt lenses.	SM-SP
S-11	54-56'	0.7'	bkg.	17,19,24,26	Brown fine sand, trace silt, with horiz. rust-brown staining, saturated, poorly graded, dense.	SP
S-12	59-61'	0.9'	bkg.	25,21,26,28	Similar to S-11.	SP
S-13	64'-66'	2.0'	bkg.	7,7,5,11	Similar to S-11, medium dense.	SP
S-14	69-71'	0.1'	bkg.	22,23,26,27	Brown fine to coarse sand, trace fine gravel, silt, well graded, dense, saturated, cobbles at 72-73'	SP
S-15	74-76'	0.7'	bkg.	18,16,17,14	Brown fine sand, trace silt, medium to coarse sand, gravel, saturated, poorly graded, dense.	SP

SOIL BORING LOG FORT DEVENS, MA PROJECT NO.: 8740.02

CLIENT: USAEC
CONTRACTOR: EEI
LOGGED BY: LT
METHOD: DRIVE & WASH
CASING SIZE: 5" TO 29', 4" TO 149', 3" TO 194'
DATE STARTED: 4/14/97
DATE COMPLETED: 4/29/97
PROTECTION: D

BORING NO.: G6M-97-29X
STUDY AREA: AOC-50
SOIL DRILLED: 190.5'
TOTAL DEPTH: 204.0'
WATER LEVEL: 56'
PID METER: 580B OVM

SAMPLE NO.	DEPTH	REC.	PID (ppm)	BLOWS PER 6"	SOIL/ROCK DESCRIPTION AND PHYSICAL CONDITIONS	USCS
	79-81'	NR		24,21,25,22	No recovery. Encountered gravel and cobbles at 79-84'.	
S-16	84-86'	0.1'	bkg.	20,21,20,27	Brown fine to coarse sand, trace silt, with gravel, saturated, well graded, dense. Encountered gravel and cobbles at 84-89'.	SW
S-17	89-91'	0.8'	bkg.	26,26,30,28	Brown fine sand, trace medium to coarse sand, silt, saturated, poorly graded, very dense.	SP
S-18	94-96'	2.0'	bkg.	28,38,30,40	Similar to S-17 to ~95.5'. 95.5'+: brown fine to coarse sand, trace silt, fine gravel, well graded, very dense.	SP SW
S-19	99-101'	0.1'	bkg.	21,28,33,36	Brown fine sand, trace silt, medium to coarse sand, saturated, poorly graded, very dense.	SP
S-20	104-105'	0.2'	bkg.	24,24,21,23	Brown fine to coarse sand, trace silt, gravel, saturated, well graded, dense.	SW
S-21	109-111'	0.7'	bkg.	22,23,33,37	Alternating layers of brown fine to medium sand, trace silt, coarse sand, gravel and silty fine sand, saturated, poorly graded, very dense.	SP-SW
S-22	114-116'	0.5'	bkg.	40,46,34,35	Brown gravelly fine to coarse sand, little-trace silt, saturated, well graded, very dense.	SW
S-23	119-121'	0.8'	bkg.	24,26,25,30	Brown fine sand, trace medium to coarse sand, gravel, saturated, poorly graded, very dense.	SP
S-24	124-126'	0.3'	bkg.	24,20,31,39	Brown fine to medium sand, trace silt, coarse sand, gravel, saturated, poorly graded, very dense.	SP
S-25	129-131'	0.9'	bkg.	24,30,30,32	Similar to S-24 to 129.5'+ 129.5'+: brown fine sand, trace medium to coarse sand, little silt, saturated, poorly graded, very dense.	SP-SM
S-26	134-136'	0.8'	bkg.	29,31,45,56	Alternating layers of brown fine sand, trace silt and silty fine sand with trace clay lenses (<1/4" thick), saturated, wet, poorly graded, very dense.	SP-SM
S-27	139-141'	1.2'	bkg.	25,36,43,49	Brown silty fine sand with a fine to medium sand, trace silt layer at ~141' (1" thick), saturated, poorly graded, very dense.	SM
S-28	144-146'	1.4'	bkg.	23,28,34,53	Brown silty fine sand transitioning to olive brown fine sandy silt with depth, saturated, poorly graded, very dense.	SM-ML
S-29	149-151'	1.3'	bkg.	32,39,49,49	Olive brown silty fine sand, with rust-brown streaking, saturated, poorly graded, very dense.	SM

SOIL BORING LOG **FORT DEVENS, MA** **PROJECT NO.: 8740.02**

CLIENT: USAEC
CONTRACTOR: EEI
LOGGED BY: LT
METHOD: DRIVE & WASH
CASING SIZE:
DATE STARTED: 4/14/97
DATE COMPLETED: 4/29/97
PROTECTION: D

BORING NO.: G6M-97-29X
STUDY AREA: AOC-50
SOIL DRILLED: 190.5'
TOTAL DEPTH: 204.0'
WATER LEVEL: 56'
PID METER: 580B OVM

SAMPLE NO.	DEPTH	REC.	PID (ppm)	BLOWS PER 6"	SOIL/ROCK DESCRIPTION AND PHYSICAL CONDITIONS	USCS
S-29	149-151'	1.3'	bkg.	32,39,49,49	Olive brown silty fine sand, with rust-brown streaking, saturated, poorly graded, very dense.	SM
S-30	154-156'	1.3'	bkg.	12,27,38,45	Alternating layers of olive-brown silty fine sand and fine sand, little silt to ~155', 155.5'+ brown fine to medium sand, little silt, trace coarse sand, gravel, saturated, poorly graded, very dense.	SM
S-31	159-161'	0.9'	bkg.	31,39,78,50	Brown fine to medium sand, little silt, little-some gravel, trace coarse sand, saturated, well graded, very dense.	SP-SM
S-32	164-166'	1.2'	bkg.	57,44,54,60	Alternating layers of brown fine sand, trace silt, fine to coarse sand, and silty fine sand, occasional silt lenses (1/4-1/2" thick), saturated, poorly graded, very dense.	SW
					Wash 169-174': brown fine to coarse sand with gravel.	
					Wash 179-184': brown fine sand.	
					Wash 184-190.5': brown fine to coarse sand with gravel. 190.5': weathered phyllite (bedrock). Advanced rollerbit and 3" spun casing to 194'. Collected rock core samples below 194'. See rock coring log.	

RESPONSE TO COMMENTS

DRAFT WORK PLAN
PILOT SCALE EVALUATION OF HYDROGEN RELEASE COMPOUND FOR ENHANCED NATURAL ATTENUATION AT AOC 50

DEVENS RESERVE FORCES TRAINING AREA
DEVENS, MASSACHUSETTS

CONTRACT DACA-31-94-D-0061
DELIVERY ORDER NO. 0007

U.S. ARMY CORPS OF ENGINEERS
NEW ENGLAND DISTRICT
CONCORD, MASSACHUSETTS

APRIL 2000

Printed On Recycled Paper

RESPONSE TO COMMENTS

DRAFT WORK PLAN
PILOT SCALE EVALUATION OF HYDROGEN RELEASE COMPOUND FOR ENHANCED NATURAL ATTENUATION AT AOC 50

APRIL 2000

USEPA Comments Dated January 26, 2000

General Comments

USEPA General Comment No 1: EPA generally concurs with the proposed pilot-scale evaluation; the document is concise and well-written, and data from the pilot will be of great benefit to the forthcoming FS. At the same time, EPA notes that numerous comments concerning the downgradient extent of the plume, the nature of ground water interaction with surface water, particularly as it pertains to plume morphology, and the adequacy of the downgradient monitoring network remain unresolved. Potential risks to ecological receptors are therefore not known at present. Furthermore, the proximity of the proposed test location to the Nashua River, coupled with the relatively high ground water velocities in this area argue strongly for the need to resolve these issues prior to potentially altering the system through initiating the pilot study. At a minimum, further delineation of the plume limits and improvement of the permanent monitoring network downgradient of the proposed test location needs to occur on a parallel track with pilot testing. This is essential for a number of reasons, which include, in the short term, enabling a meaningful evaluation of the pilot test downgradient of the test area, as well allowing for a meaningful assessment of MNA processes and efficacy over the long term. A meeting should be scheduled in order to discuss these issues in the context of the proposed pilot study.

Response: The major purposes of the pilot study are to confirm whether conditions conducive to anaerobic biodegradation of PCE can be established at AOC 50 and to obtain data useful for full scale design. The pilot test is not intended to answer questions concerning plume delineation or to complete a permanent monitoring network, although any new monitoring wells will be available for long-term monitoring. Down-gradient monitoring wells will be completed at locations considered appropriate for evaluating the pilot test.

The Army is available for discussion of further delineation of plume limits and the required extent of the permanent monitoring network.

USEPA General Comment No 2: Additional comments may be forthcoming once EPA has had an opportunity to review the Final RI for AOC 50, dated January 2000, which EPA has just received.

Response: No response necessary.

USEPA General Comment No 3: EPA would appreciate any case-study information which the Army may have relative to HRC application at analogous sites.

Response: Case study information was made available to interested parties at the March 9 RAB meeting. Additional material can be provided.

Page Specific Comments

USEPA Comment No. 1; Page 4-1, Section 4.1: Additional explanation/rationale is needed concerning the various criteria considered during selection of the proposed pilot test area. How were these criteria generated ? Were these supplied by the vendor ? EPA notes that hydraulic conductivities and ground water velocities at the test location appear to be favorable. However, dispersion appears to be very weak in this aquifer as suggested by the plume morphology. Are high hydraulic conductivities, in and of themselves, sufficient to Aallow for effective distribution of electron donor@ ? How will dispersivity be evaluated relative to pilot performance ?

Response: The first, third, and fourth criteria were adapted from "A Treatability Test for Evaluating the Potential Applicability of the Reductive Anaerobic Biological In Situ Treatment Technology (RABITT) to Remediate Chloroethenes" (Environmental Security Technology Certification Program (ESTCP), U.S. DoD, February 1998).The remaining criteria were added to simplify data interpretation and pilot test implementation.

Based on assessment of plume configuration interpreted from field screening data and groundwater modeling results, vertical dispersion is expected to be low in the vicinity of the pilot test and play a minor role compared to lateral dispersion. It is unlikely that vertical dispersion could be observed across the dimensions of the pilot test. However, to minimize possible effects from vertical dispersion and/or vertical gradients at the upper and lower surface of the HRC™ plume (i.e., fringe effects), the pilot test proposes to inject HRC™ over a 20-ft interval and monitor a narrower vertical interval. The spacing between points is based on a software program developed by Regenesis and on measured concentrations of DO, NO_3, SO_4, and PCE, as well as on independent assessment by the Army. Spacing of monitoring wells has been made purposefully close. The Army expects that the results of the pilot test will help bound or more tightly determine lateral dispersivity values.

USEPA Comment No. 2; Page 4-2, 1st bullet: Why is it important to have low concentrations of BTEX ? Generally, elevated BTEX are described as enhancing reductive dechlorination processes. Are other potential sources of organic carbon potentially problematic ? Should the pilot test involve collecting supplemental organic carbon data from strata directly within the proposed pilot test area ?

Response: Low concentrations of BTEX were incorporated as a criteria to keep the effects of BTEX induced anaerobic conditions separate from pilot-test induced anaerobic conditions.

Table 2, Sample Collection Schedule, includes collection of TOC data.

USEPA Comment No. 3; Page 4-2, 1st full paragraph: The comparison of past screening data with monitoring data from permanent wells underscores the need to improve the permanent monitoring network proximal to the proposed test location. Please see general comment 1, above.

Response: Please see response to General Comment No. 1.

USEPA Comment No. 4; Page 4-2, 2nd full paragraph, last sentence: Typo. Shouldn't ground water velocity read A0.3 ft./day@ here ?

Response: Yes. The sentence will be corrected to read as follows:

"At a groundwater velocity of 0.3 ft./day...."

USEPA Comment No. 5; Page 4-3, top. How were the proposed quantities of HRC determined ? Over what time period will the injection take place ? (i.e. Arate@). Are there any other means of assessing the extent of the resulting HRC Acones@ ? Please elaborate on the potential Afringe effects@, particularly how this relates to assumptions concerning dispersivity. This is a key issue in that the efficacy of dispersion, both in the lateral and vertical dimensions, will dictate the density of injection points needed to effectively treat a given area. In this respect, an accurate assessment of the HRC technology at the pilot scale should seek to thoroughly evaluate the effects of dispersion. The Army's intention to conduct tracer tests is well-aligned with this issue, but EPA notes that a greater level of vertical monitoring may be needed at the down-gradient monitoring locations. EPA recommends that nested wells (e.g., 3 to 4 discrete screens), be installed at each of the four downgradient locations indicated on Figure 4.

Response:

(a) The proposed quantities of HRC™ were based on calculations performed by a software program developed by Regenesis and on measured concentrations of DO, NO_3, SO_4 and PCE at MAAF. Inputs have been modified since preparation of the draft, and the subject sentence will be edited to read as follows:

"Injection will be accomplished over a 2-to 3-day period by pushing five drive points spaced six feet apart to the maximum injection depth and then injecting HRC™ at a rate of approximately 6.3 lbs. per foot over the 142 to 122 ft. bgs. interval as the point is withdrawn."

(b) Injection would occur over a 2-to 3- day period as indicated above.

(c) Please refer to the response to USEPA Page-specific Comment No. 1.

(d) The Army agrees that horizontal dispersion is an important design variable. The tracer study is intended to help answer questions about the required density of injection points for full scale design.

(e) Please refer to the response to USEPA Page-specific Comment No. 1. Nested downgradient monitoring wells would be expected to provide little useful information on vertical dispersivity.

USEPA Comment No. 6; Page 4-3; Section 4.4: What is the potential that the duration of the pilot may be greater than expected ?

Response: The schedule for the test has been developed based on the best estimates of groundwater plume migration velocities and the time needed to for microbial degradation to occur. It is possible that conditions local to the pilot test may be different than present estimates, and may cause reassessment of sampling intervals. The probability that the duration of the pilot test will be longer than expected is not known.

USEPA Comment No. 7; Page 4-3 to 4-4: Well Construction; EPA does not concur with the Army's proposal to incompletely build monitor wells for the pilot for several reasons. First, low-flow sampling, which the Army intends to conduct, is predicated on properly constructed monitoring wells (i.e., with properly constructed sand packs, seals, etc.). Second, MNA evaluation will involve measurement of various inorganics, such as iron, which may be compromised by improperly constructed wells. Therefore, EPA strongly recommends that the Army takes advantage of the minor incremental costs in view of the benefits to long-term objectives such as improving the permanent LTM network.

Response: The sentence at the bottom of page 4-3 in the draft Work Plan will be edited to read as follows:

> "Sand pack will extend 5 feet above the top of the screen, a 5-ft bentonite seal will be place above the sand, and the well annulus will be grouted to the ground surface."

USEPA Comments Dated February 14, 2000

General Comments

USEPA General Comment No. 1: There are four stated objectives of the pilot scale testing given on page 2-1. It is believed that an additional objective should be included: development of scale-up parameters for

full scale design. These parameters may include the following: HRC loading rates; HRC injection pattern depending on varying hydraulic dispersivity, conductivity, and groundwater velocity throughout the plume; and estimated costs. The work plan should include a listing of all data and parameters needed for scale-up, and outline what information will be presented in the final pilot study report. In particular, the work plan should include a discussion of the need for any computer models and the input data needed for scale-up. With this information, an assessment can be made whether sufficient data is being collected in the pilot study to achieve the desired result of evaluating both the effectiveness of the HRC process and ability to develop and cost a full scale design from the pilot study results.

For example, in areas of lower hydraulic conductivity, the grid used for injection of HRC in full scale design may require a tighter grid spacing where either the travel time or the length of the migration path of dissolved hydrogen is relatively short. The pilot study report should indicate how this issue would be addressed in full scale design.

Response: The following wording will be added to Section 3.0.

> "Full scale implementation of enhanced in-situ bioremediation using HRC™ would require consideration of hydraulic dispersivity, conductivity, and groundwater velocity. A software program developed by Regenesis considers these factors to calculate HRC™ loading rates for either barrier or grid injection patterns. Data from the pilot test will be used to confirm the applicability of the enhanced bioremediation program and confirm dispersivity assumptions."

USEPA General Comment No. 2: The location selected for the pilot test is reasonable given the constraints of hydraulic conductivity and accessibility. Ideally, a pilot study location at one of the a highest concentrations of PCE would be preferable to demonstrate the worst case scenario. It is recommended that a pilot study of in situ permanganate oxidation be considered for those areas where there is either a much higher chlorinated organic concentration or reduced hydraulic conductivity, or both.

Response: The Army agrees that in-situ permanganate oxidation has potential for areas of higher concentration and/or lower hydraulic conductivity such as the source area. However, the Army only has plans to pilot test HRC™ at this time.

USEPA General Comment No. 3: In general, the ideal pilot test of HRC would utilize injection points along a line that is perpendicular to the plume centerline. Monitoring points would be along a parallel line to the injection both upgradient and downgradient to the injection line. Such an injection pattern is partially shown in Figure 4. However, it appears that additional wells are needed. See specific comment 9.

Response: Please refer to response to USEPA Page-specific Comment No. 9.

USEPA General Comment No. 4: It is noted that the primary groundwater contaminants of concern for the indoor air exposure pathway are vinyl chloride (VC), 1,1 dichloroethene (DCE), and 1,2 dichloroethane(DCEA) due to their higher toxicity by the inhalation pathway and the shallow depth of approximately 15 feet to groundwater near Building 3803. It is important that any pilot tests consider the need to demonstrate that these compounds can be destroyed. This should be discussed in the text.

Response: Please see response to the following Comment (No. 5).

USEPA General Comment No. 5: The HRC will assist with microbial dehalogenation of PCE and TCE to form DCE by anaerobic pathways. However, HRC will not enhance the biodegradation from DCE to VC to ethene, which is much slower under anaerobic conditions than the transformation of PCE and TCE to DCE. Therefore, HRC alone as a remedial alternative for the enhancement of microbial transformation of PCE and TCE to DCE with natural attenuation of DCE to VC and ultimately ethene is not acceptable, because it would tend to accumulate DCE and VC in groundwater underneath the existing building and any future buildings. The HRC remedial alternative should include some method for the enhancement of microbial dehalogenation of DCE to VC and ethene by creating an aerobic zone downgradient from the anaerobic zone where the HRC is used. Oxygen addition to the groundwater in the form of ORC or hydrogen peroxide may be necessary in a zone downgradient from the zone where HRC is added to increase the oxygen concentration to near saturation for enhancement of microbial degradation of DCE to VC and ethene. These issues should be considered in the selection of the technology to be pilot tested. Please discuss this in the text. See reference 1. [Proceedings of the First International Conference on Remediation of Chlorinated and Recalcitrant Compounds. May, 1998. Volumes 1- 6. Battelle Press. Columbus, Ohio.]

Response: The next to last sentence in the first paragraph of Section 3.0 will be edited to read as follows:

> "Studies have shown that PCE and TCE are degraded quickly to DCE under anaerobic conditions. The degradation of DCE to VC and VC to ethene is slower, but does occur under strongly reducing conditions without the use of oxygen enhancements ("Technical and Regulatory Requirements for Enhanced In Situ Bioremediation of Chlorinated Solvents" Interstate Technology and Regulatory Cooperation Workgroup, 1998). Monitoring during the pilot test will allow assessment of DCE and VC degradation within overburden groundwater."

It should be noted that the pilot test is not proposed near any buildings nor has full-scale implementation been proposed near source-area buildings where the depth to groundwater is shallow. Further, at the

proposed test location, the plume is not at the water table surface, and the vadose zone thickness is considerable.

USEPA General Comment No. 6: The HRC may have very little impact on the chlorinated organics in groundwater within the weathered bedrock due to limited mixing. Please discuss this in the text.

Response: The introductory paragraphs of Section 4.0 will be edited to read as follows:

> "... This approach may require multiple injections and take longer than the grid-based approach, but be more cost effective for large areas. Regenesis' experience is that HRC™ can be formulated and injected such that it will persist for up to a year before complete dissolution/dispersion, at which time reinjection is necessary. The length of time needed to cleanup a groundwater plume is inversely proportional to the number of injection/treatment barriers (e.g., installation of two treatment barriers, one at the toe of a plume and one at the midpoint would cut cleanup time in half).
>
> Based on these considerations, HLA proposes testing the barrier design approach for treating overburden groundwater. The portion of the plume proposed for testing is not closely associated with underlying bedrock, and assessment of HRC™ effectiveness for bedrock remediation is not planned. In addition, it is believed that the PCE migration pathway in bedrock at AOC 50 is short and that the plume re-emerges into the overburden aquifer where it would be more readily treated.
>
> Information from the test (e.g., assessment of process feasibility, characterization of microbial processes, degradation rates, and dispersivity) would, however, also have applicability to a full-scale grid-based design. The Feasibility Study will examine optimal strategies for HRC™ application from time and cost standpoints."

USEPA General Comment No. 7: If monitored natural attenuation is ultimately proposed in certain areas of the site as a part of a remedial alternative, it should be recognized that institutional controls to restrict development of future buildings where groundwater contaminants could pose an indoor air health risk may be necessary.

Response: The Feasibility Study will assess the need for institutional controls in conjunction with other remediation technologies.

USEPA General Comment No. 8: If the oxidation-reduction potential (ORP) over the pilot study area or the entire site is within the range that is indicative of anaerobic conditions, it would be expected that the rate of microbial transformation from DCE to VC will be very slow and at a rate that is slower than the transformation from PCE to TCE and TCE to DCE under anaerobic conditions. It is important that the pilot study investigate the rate of biotransformation between chlorinated organics compounds, such as DCE to VC. Please discuss this in the text and specify that the rate of transformation between the various chlorinated organics (PCE, TCE, DCE, and VC, etc.) will be evaluated and reported.

Response: The third bullet of Section 2.0 will be edited to read as follows:

- "collecting data to estimate the rate of sequential dehalogenation of PCE, TCE. DCE, and VC"

Page Specific Comments

USEPA Comment No. 1; Title Page: The title is "...Hydrogen Release Compound for Enhanced Natural Attenuation". This is somewhat of a misnomer, because Hydrogen Release Compound does not enhance natural attenuation, which would include all of the other attenuation mechanisms of dispersion, adsorption and volatilization in addition to intrinsic bioremediation. HRC enhances only the bioremediation component of natural attenuation. Therefore, the words "enhanced natural attenuation" should be replaced with "enhanced bioremediation" when used with HRC throughout the report.

Response: Considering that human intervention by injecting of HRC™ is not a natural process, the words "enhanced natural attenuation" will be changed to "enhanced in-situ bioremediation".

USEPA Comment No. 2; Section 2.0, page 2-1: The third objective states that one objective is "collecting data to estimate the rate of degradation". This objective should be expanded to include comparing the estimated rate of degradation of this pilot study to reported values from other pilot study and full scale tests to insure that the rate is comparable.

Response: While the Army is willing to provide some references for apparent rates, it should be realized that they will span a large range (e.g., half lives from days [high rate] to years [low rate]), and may provide only a qualitative measure of comparability. No change to the text is proposed in response to this comment; however, please see response to USEPA General Comment No. 8 (February 14, 2000).

USEPA Comment No. 3; Section 2.0, page 2-1: The fourth objective is to estimate dispersivity. Please indicate whether this is both lateral and longitudinal dispersivity.

Response: The forth bullet of Section 2.0 will be edited to read as follows:

- collecting data to estimate lateral dispersivity; this will be useful to full scale remedial design

USEPA Comment No. 4; Section 4.0, page 4-1, paragraph 1: The text indicates that "one approach is injection along a row of delivery points oriented perpendicular to groundwater flow to create a treatment barrier. This approach may require multiple injections ...". Please discuss how it would be determined when to do a second or third injection and how the proposed pilot test would address the need for multiple injections of HRC. The need for multiple injections could greatly impact the full-scale cost of remediation. It is not clear how the pilot test will assess the need for multiple injections of HRC and the associated full-scale costs.

Response: Please refer to the response to USEPA General Comment No. 6 (February 14, 2000).

USEPA Comment No. 5; Section 4.0, page 4-1, paragraph 1: The text states that "information from the test would, however, also have applicability to a full-scale grid-based design". Please state what specific information will be gained that would have applicability to full-scale design.

Response: Please refer to the response to USEPA General Comment No. 6 (February 14, 2000).

USEPA Comment No. 6; Section 4.1, page 4-2, paragraph 1: One of the criteria for siting the pilot study is that "concentrations of BTEX in groundwater should not be elevated ....". It is suggested that a BTEX contour plot be included in this report or overlain on the PCE contour plots so that the reader can see the BTEX concentrations throughout the PCE plume.

Response: Review of data presented in the RI report indicates that benzene concentrations are sufficiently low that preparing overlying figures would not be useful to selection of pilottest locations. No additional figures are planned.

USEPA Comment No. 7; Section 4.1, page 4-2, paragraph 3, last sentence: The text incorrectly states that "at a groundwater velocity of 0.03 ft/day, 30 and 60 day travel times...." The text should be corrected to state that "at a groundwater velocity of 0.3 ft/day ...".

Response: The text will be corrected to read as follows:

"At a groundwater velocity of 0.3 ft/day ...".

USEPA Comment No. 8; Section 4.1, page 4-2, paragraph 3: The text discusses the computed travel times desired between monitoring wells, but it does not discuss whether any retardation factor was used to compute the travel times. Please discuss this issue in the text.

Response: The following sentence will be added to the third paragraph of Subsection 4.1:

"These distances are based on groundwater velocities, without adjustment for retardation."

USEPA Comment No. 9; Figure 4: Two additional upgradient wells along a line parallel to the HRC injection points and intersecting well MW-1 should be included in this figure so as to completely assess the upgradient contaminant profile prior to groundwater entering the HRC treatment zone. The upgradient and downgradient monitoring wells and HRC injection points shown in Figure 4 should also be superimposed on Figures 1, 2, and 3 to show the plan view collocation of the HRC pilot test with the existing wells and PCE plume and to show in the vertical profile the depth of the well screens on those monitoring wells used in the pilot test. For example, one cannot know where well GM-98-32x is located in relation to the proposed monitoring wells and HRC injection points.

Response: Although more monitoring wells would provide increased contaminant profiling of upgradient groundwater, it is believed that the objectives of the pilot test can be met with the proposed monitoring wells. Groundwater samples will be collected from all the monitoring wells according to the schedule in Table 2. Considering the closeness of the monitoring wells (i.e., five wells in a 30- by 44-ft area), groundwater within the treatment zone should be well characterized. Further, limiting the number of monitoring wells will limit the disturbance of aquifer materials and potential introduction of drilling water.

The network of injection points and monitoring wells shown in Figure 4 will be located immediately north of G6M-98-32X and the service road that runs along the southwest edge of MAAF.

An in-text table has been added to Subsection 4.1 to document the depths/elevations with highest PCE concentrations. Proposed injection and monitoring well depths given in Subsections 4.2 and 4.3 have been calculated to intersect this high concentration interval. Because monitoring well G6M-98-32X was constructed with only a 5-ft screen, it is no longer planned to be among the primary monitoring wells for the pilot test.

MADEP Comments Dated December 22, 1999

MADEP Comment No. 1; Section 4.2 HRC™ Injection: Please provide more detail describing what is meant by the "fringe effects" that are trying to be minimized in the more narrowly screened monitoring wells by the injection of HRC™ over a 20-ft interval.

Response: Please refer to the response to USEPA Page-specific Comment No. 1 (January 26, 2000).

MADEP Comment No. 2; Section 4.2 HRC™ Injection: The Plan calls for injecting HRC™ over an interval of 140 to 120 feet below ground surface (ft-bgs) in the vicinity of XGM-98-32X. A review of the Figure 2 Distribution of PCE in Groundwater Along Cross Section A-A' shows the vertical distribution of the PCE plume to be from a depth of 115 to 160 ft-bgs. While the upper limit of the proposed injection interval appears to be proximal to the upper limit of the PCE distribution, the lower limit coincides with the lower PCE 1,000-ug/l concentration contour.

MADEP understands that interpreted geologic conditions at depth in this area consist of finer materials than that in the center or upper portions of the plume. However, these conditions based on the geologic history and boring logs, show a stratification of coarser and finer materials through which groundwater flow is predominantly horizontal. Historically, PCE has on one occasion been detected at depth in G6M-97-29X, which is placed with the screen just above bedrock. However, MADEP understands that the Army attributes the PCE detection to laboratory or sampling and handling error. The presence of PCE in this geologic media would likely be attributed to groundwater entering from an upgradient location, as opposed to vertical dispersion from above. Therefore, the HRC™ injected in a zone above will unlikely provide a beneficial impact to groundwater within or below this area. Therefore, MADEP recommends that the Army and its consultant evaluate the necessity of extending the vertical HRC™ injection interval deeper. Please provide a discussion for the selection of the HRC™ injection interval not to extend deeper into the aquifer to encompass more of the plume.

Response: The objectives of the pilot test are to assess whether conditions suitable for anaerobic degradation of PCE can be induced and to better characterize several process variables. Injection across the full thickness of the plume is not necessary to do this. There is no supposition that injection at the 120 to 140 ft bgs interval will treat groundwater at the 180 ft bgs depth of the G6M-97-29X screen.

The following sentence will be added near the end of the first paragraph of Subsection 4.2:

"Injection across a wider vertical interval is not necessary to meet pilot test objectives."

MADEP Comment No. 3; Section 4.3 Location of Groundwater Monitoring Wells: The Army proposes to install monitoring wells downgradient of the injection locations to monitor groundwater quality and the effects of dispersion of the HRC™ material. The proposed monitoring wells will be constructed of 10-foot screens. These wells may be adequate to monitor the effects of dispersion along horizontal groundwater flow paths. However, these wells will not be able to monitor vertical dispersion of the compound. This is particularly important with regard to deeper CVOC-contaminated groundwater. MADEP recommends that well locations consist of monitoring well nests or couplets to provide additional information on vertical PCE distribution prior to the HRC™ injection and dispersivity of the HRC™ following injection (see following comment). At a minimum, there should also be some discussion as to the vertical dispersion of the HRC™ and the need for being able to evaluate vertical dispersivity.

Response: The existing interpretation of PCE distribution and plume dimensions is based on extensive horizontal and vertical profiling described in the RI report, the Army has no plans to repeat that that effort.

Please refer to the response to USEPA Page-specific Comment No 1 (January 26, 2000) and to the response to the following comment.

MADEP Comment No. 4; Location of Groundwater Monitoring Wells: The contaminant distribution shown on the cross-sections is based on interpretation of screening data collected in 1996 to 1997 field program. Due to time intervals between well installation, groundwater sampling rounds, recent analytical results, and groundwater movement the shape and distribution (horizontal and vertical) of dissolved CVOCs has likely changed. Variations are evident in the monitoring events of 1999. Field screening for CVOCs during borehole advancement associated with the monitoring well installation would provide valuable information to accurately define the plume vertically within the treatment area and may subsequently affect the decision on HRC™ injection interval and the final well screen placement.

Response: The following wording will be added to Subsection 4.3:

> "To confirm the appropriateness of the planned depth and location of monitoring wells and injection points, groundwater samples will be collected with a hydropunch or equivalent from the proposed upgradient well over the approximate 120 to 140 ft bgs interval for field analysis/screening with a PhotoVac 10S Plus, Portable Gas Chromatograph. The planned location and depth of monitoring wells and injection points may be changed based on the monitoring data."